Radiometric Calibration Validation of the Hyperion Instrument using Ground Truth at a Site in Lake Frome, Australia

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ABSTRACT

The Hyperion instrument mounted on the EO-1 spacecraft was launched November 21, 2000 into an orbit following LANDSAT-7 by 1 minute. Hyperion has a 7.5 km swath width, a 30 meter ground resolution and 10 nm spectral resolution extending from 400 nm to 2500 nm. The first portion of the mission was used to measure and characterize the on-orbit radiometric, spectral, image quality and geometric performance of the instrument. Lake Frome, a dry salt lake in South Australia was chosen as a calibration site for Hyperion. Surface spectral data were collected along a transect through the center of the lake prior to the Hyperion overpass. This paper discusses the incorporation of the Lake Frome ground measurements and analysis into the performance verification of the instrument.

Keywords: Hyperspectral Imaging, Radiometric Calibration, Ground Truth, Lake Frome, Hyperion, EO-1

1. INTRODUCTION

Vicarious calibration provides a unique opportunity to investigate the characteristics of the instrument from a direction that is user oriented. The process involves extensive ground truth and coordination with spacecraft mission operations to coordinate the time of data collection of the spacecraft with the ground truth measurements. The result is a direct comparison of the top of atmosphere (TOA) measurements made by the instrument with the top of atmosphere prediction based on the independently measured ground spectral reflectance measurements and propagation through a modeled atmosphere.

The absolute radiometric calibration of the responsivity of the Hyperion instrument performed on the ground prior to launch is described by Jarecke[1]. The on-orbit verification approach was to transfer the pre-flight calibration to on-orbit operation and compare the Hyperion measured solar irradiance with solar models. The Hyperion agreement with the absolute solar spectral irradiance was ± 3 % in the VNIR and Hyperion was 5 to 8 % below the solar model in the SWIR. The absolute verification is supplemented with lunar calibration collects and vicarious collects such as the Lake Frome campaign.

The EO-1 spacecraft is in a sun-synchronous orbit with an altitude of 705 km and a 10:01 AM descending node. The spacecraft view of the ground has a sixteen day repeat cycle. A field measurement campaign was undertaken at Lake Frome to coincide with a Hyperion overpass on December 20, 2000. Further atmospheric measurements were taken at the time of the next overpass on January 5, 2000. Hyperion images were collected on December 20, 2000 and January 5 and 21, 2001. The January 5th collect was the primary collect used in the study. Lake Frome is an ideal site as the Hyperion ground track aligns with a well established and persistent salt track.

Top of the atmosphere radiances from the Lake Frome sites at the time of the overpass were estimated by the CSIRO team for January 5th and compared with the top-of-the-atmosphere radiance levels measured by Hyperion. This paper discusses the field measurement campaign and the results of the top-of-the-atmosphere comparison.

2. LAKE FROME FIELD MEASUREMENTS

Lake Frome is located in the north east of South Australia and is a large, normally dry salt lake (playa). The center of the playa is approximately at Latitude: 30^{o}51'S and Longitude: 139^{o}45'E. Fig. 1 is an image of the Hyperion pass over the Lake Frome area showing the field sites. Notice that the sites fall on a path along the center region of the Hyperion swath. Figure 2 is a photograph of a salt playa during a field measurement. The data collected as part of the Lake Frome vicarious calibration effort include spectral, navigation, and atmospheric data.

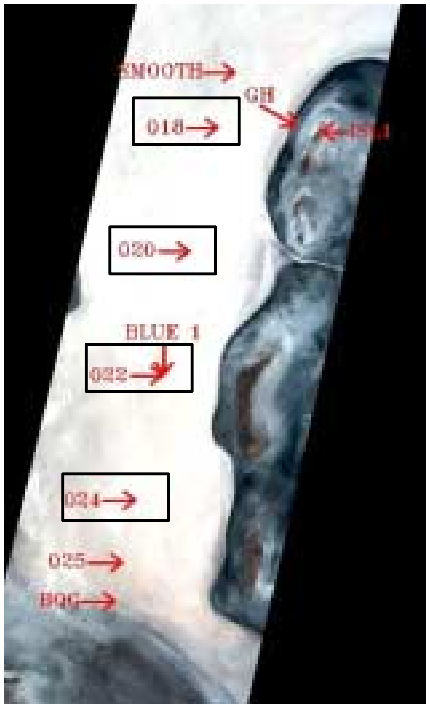

Figure 1: **Lake Frome image taken by Hyperion January 5, 2001.**

Figure 2: **Photograph of salt playa during a field measurement**

Using a field design and logistics described more fully in Graetz et al.[2] the field party visited selected sites during a four day period prior to the December 20 overpass. Spectral measurements were taken with an ASD Fieldspec spectroradiometer and a GER 37000 spectroradiometer referenced to a Spectralon panel. All positions were accurately recorded with a Global Positioning System (GPS). These GPS readings provided a very accurate base to geo-locate the VNIR and SWIR data with other platforms. This was used to define the SWIR to VNIR co-registration. The spectral measurements were made over specified ground blocks to account for spatial variation and the mean signatures were established. A subset of the sites that were measured is listed in Table 1. Also include in Table 1 is the Hyperion VNIR and SWIR pixel corresponding to the field measurement location. Note that the ground truth sites selected in the analysis correspond to nearly a single field of view location. These sites were used for the comparison with Hyperion measurements.

TABLE 1
SITES CHARACTERIZED FOR COMPARISON WITH HYPERION

Name	Site Description	Latitude	Longitude	VNIR Pixel	VNIR Line	SWIR Pixel	SWIR Line
018	Uniform Salt	-30.80	139.68	107	2219	108	2219
020	Uniform Salt	-30.83	139.67	107	2343	108	2434
022	Mixed Salt and Mottle	-30.87	139.66	107	2467	108	2467
024	Uniform Salt	-30.90	139.65	108	2592	109	2591

Meteorological data were collected during the mission using a portable weather station and a Yankee Environmental Systems multi-frequency shadow-band radiometer (MFR) operating at the lake shore. Data were also acquired from Bureau of Meteorology radiosondes launched from Woomera (250 km west of Lake Frome) and a CIMEL sun photometer located at another CSIRO field site 150 km north of the field site.

The CIMEL data was used to provide estimates of aerosol optical depths and water vapor. The radiosondes were used to obtain lapse rates for the pressure, temperature and water vapor profiles. These measurements were combined with historical atmospheric knowledge of the region. A basic radiative transfer model was used for the initial investigation.

The field measurements were combined to perform top-of-the atmosphere comparison. The high resolution ground reflectance was convolved with the known Hyperion bandwidth and sampled at the Hyperion center wavelength, a sample is shown in figure 3. Modeling of the atmosphere enabled transfer to top-of-the-atmosphere comparison, an example is provided in figure 4.

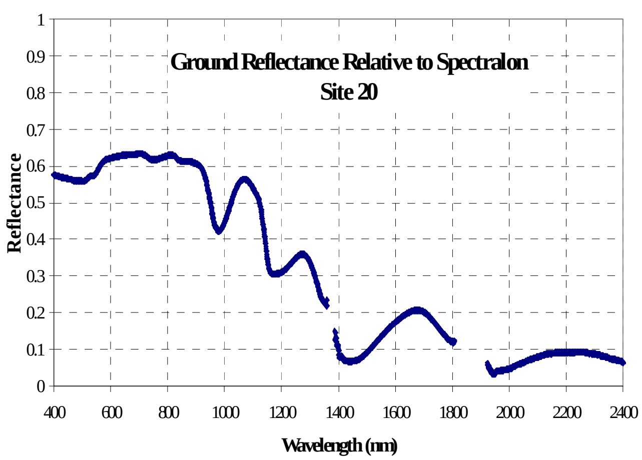

Figure 3 **Ground Reflectance Example**

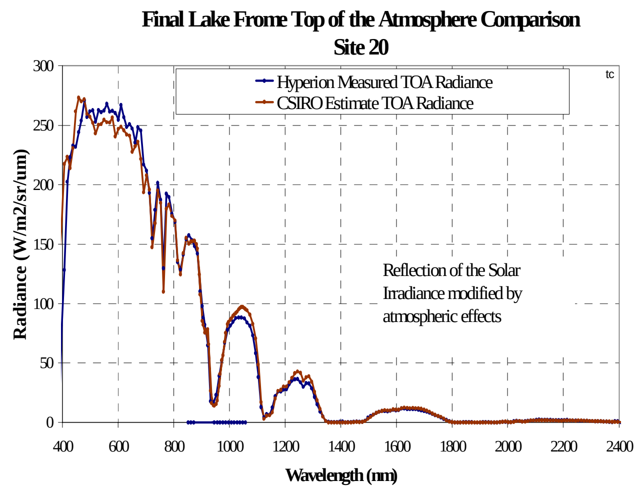

Figure 4: **Top of the Atmosphere Comparison Example**

3. RESULTS

The comparisons were performed by taking the ratio of the CSIRO field measurements transferred to the TOA to the Hyperion measured TOA. Sites 18, 20, 22, and 24 were used as the primary focus for the comparison. As indicated in Table 1, all four sites correspond to approximately the same Hyperion field-of-view location. An average of the ratio of each of the four sites is presented in figure 5. The error bars indicate the maximum and minimum difference of each of the four sites from the average of the four sites. The measurement spread was approximately 5%. The plot indicates that the Hyperion measurement of the top-of-the-atmosphere radiance is within the top-of-the-atmosphere estimates based on the field measurements. The agreement is on the 5 % level for the majority of the VNIR focal plane. The disagreement in the lower wavelengths may be attributed to the aerosol model used.

Figure 6 shows an analogous plot for the SWIR. The SWIR shows a much larger variation and a spectrally dependent variation. The measurement spread is also larger, increasing with the lower signal regimes. The spectral variation was suspect, since comparison with the solar calibration event and with the internal calibration source did not indicate a spectral variation. It is believed that the underlying spectral variation can be attributed to a change in the moisture between the time of the field measurements (December 17-20th 2000) and the time of the overpass (January 5th 2001).

To investigate this hypothesis a laboratory analysis was performed. Salt samples from site 22 were analyzed under different conditions. Figure 7 shows the results of the spectra of the salt under microwave dry conditions and then with varying amounts of water added. Using the 25 ml spectrum as the reference spectra, since that spectrum was the closest to the ground spectra shown in figure 3, ratios of different amounts of water content were calculated.

Figure 8 overlays the SWIR average TOA ratio with ratios of the salt spectra with varying amounts of water content. The comparison indicates that assuming the amount of water present in the December 20th field campaign was represented by the 25 ml of water sample, then the spectral dependency seen in the SWIR is consistent with a water content at the time of the Hyperion overpass (January 5th 2001) represented by the 20 ml of water sample. This comparison supports the hypothesis that the spectral dependence since in the SWIR TOA ratio can reasonably attributed to a change in water content of the salt, with the lower content associated with the January 5th overpass. This is consistent with weather pattern being dry during the time the two collects. Since an arbitrary offset was added ratio of the salt spectrum, this analysis does not provide information about the bias of either the field measurements or Hyperion.

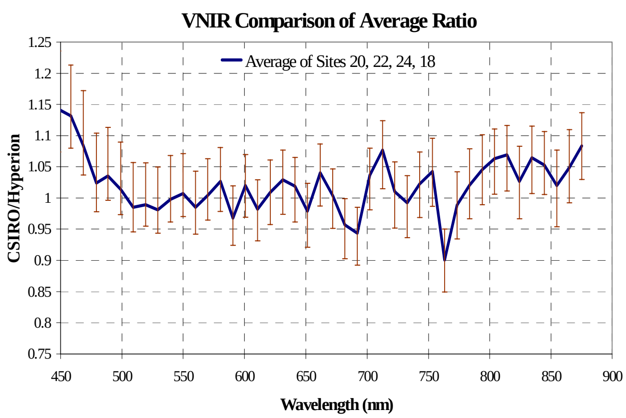

Figure 5. **VNIR Comparison of the Average Ratio**

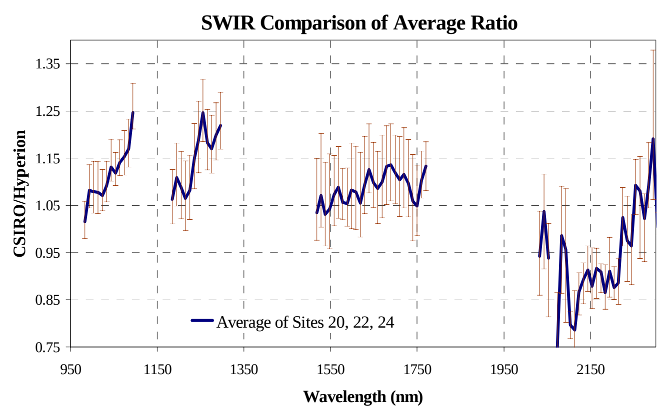

Figure 6. **SWR Comparison of the Average Ratio**

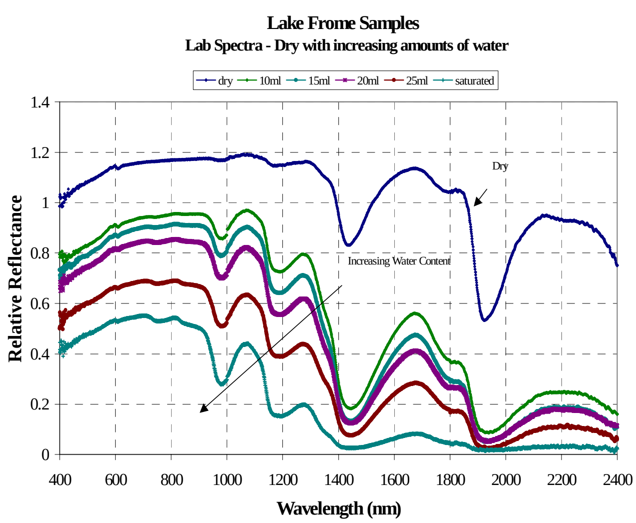

Figure 7. **Lake Frome Laboratory Moisture Analysis**

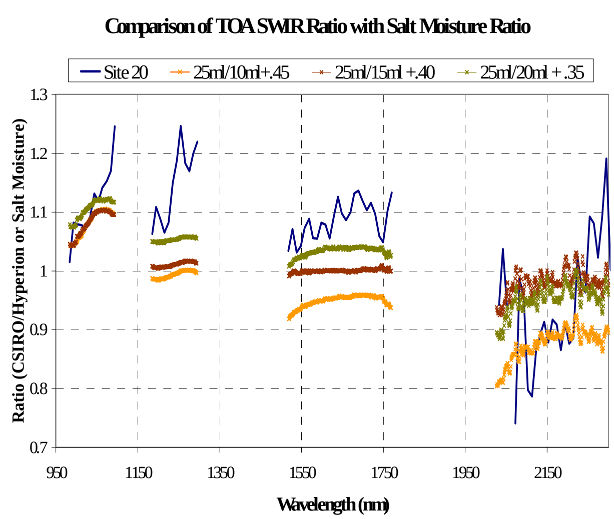

Figure 8 **Comparison of TOA SWIR ratio with Salt Moisture Ratio**

4. CONCLUSIONS

A vicarious calibration effort at Lake Frome in Australia was incorporated into the performance verification of the Hyperion imaging spectrometer instrument. The ground reflectance measurements and atmospheric correction leading to TOA radiances are consistent with the Hyperion ground and solar calibration at the 5% level in the 450 to 850 nm spectral range. The SWIR agreement is at the 10 % to 15 % with the spectral dependency of the variation being attributed to differences in moisture content between the time of the collect and the date of the Hyperion collect.

REFERENCES

1. P. Jarecke, K. Yokoyama, "Radiometric Calibration of the Hyperion Imaging Spectrometer Instrument From Primary Standards to End-to-End Calibration ", *Proc. of SPIE*, Vol. 4135 , pp.254-263, August 2000.
2. Graetz, R.D, Campbell, S., Lovell, J., King, E., & Byrne, G. (in preparation). Lake Frome, Australia: A site for vicarious calibration of broadband and narrow band sensors.